

Water Footprint Symposium: where next for water footprint and water assessment methodology?

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Abstract Recognizing the need for a comprehensive review of the tools and metrics for the quantification and assessment of water footprints, and allowing for the opportunity for open discussion on the challenges and future of water footprinting methodology, an international symposium on water footprint was organized. The Water Footprint Symposium was held in December 2013 at the University of Leeds, UK. In particular,

four areas were highlighted for discussion: water footprint and agriculture, quantification of water footprint, industrial water footprint, and from theory to practice. Discussion was organized to focus on the “prioritization of water footprint research & applications to practical sectors”. The concept of water footprinting has helped to better communicate water management and assessment among different research and user communities. Significant research progress has been made in the relations between water footprint and agriculture, quantification of water footprint, industrial water footprint, and the transition from theory to practice. Future water footprint research needs to further enhance assessment accuracy, improve sustainability assessment methodology, develop databases, address uncertainties, and prioritize application by government and in practical sectors. More information on the symposium can be found on the water@leeds website: <http://www.wateratleeds.org/conferences/2013/water-footprint-symposium>.

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1 Introduction

The number of water footprint studies and publications has increased rapidly in recent years (Hoekstra and Chapagain 2007; Liu and Savenije 2008; Ridoutt and Pfister 2009; Hoekstra et al. 2011; Hoekstra and Mekonnen 2012; Zeng et al. 2012; Chenoweth et al. 2013; Liu et al. 2013; Yang et al. 2013), and consequently, there is a need for a comprehensive review of the numerous tools and metrics developed for quantification and assessment.

The Water Footprint Symposium, organized by water@leeds, University of Leeds, UK, offered delegates an opportunity to discuss the current challenges and the future of water footprint methodology. Leading academic thinkers in the area were brought together with stakeholders from government, industry, and agriculture. Detailed information about the symposium is available for download via the water@leeds

website: <http://www.wateratleeds.org/conferences/2013/water-footprint-symposium>.

Topics of the Water Footprint Symposium included the following:

- Top-down and bottom-up methods for Water Footprint calculation
- Water footprint assessment (WFA)
- Water use in life cycle assessment (LCA)
- ISO 14046 water footprint
- Agriculture and the water footprint
- Virtual water trade
- Water valuation
- Creating a water footprint database
- Water stewardship schemes
- Company disclosure schemes
- Translating volumes into environmental impacts

2 Water footprint and agriculture

The water footprint and agriculture session was chaired by Junguo Liu (Beijing Forestry University). Tony Allan (King's College London) highlighted the role of farmers as water managers. He noted that 90 % of the water consumed by society is embedded in food supply chains. Farmers manage and potentially steward 90 % of the water consumed in food and fibre supply chains. He also pointed out water scientists overly focus on water and do not recognize that farmers have to handle a complex suite of inputs. Water scientists, water ecosystem scientists, and water economists can produce useful metrics on underlying fundamentals and on how water should be sustainably allocated and managed. But their knowledge is easily overwhelmed by priorities constructed in markets and by society. Jon Lovett (University of Leeds) gave a brief review of the water problems around the world and in the UK and pointed out the potential value of using virtual water to balance agricultural production and water problems in the UK. Bruce Lankford (University of East Anglia) reviewed the objectives and methodologies of water accounting and highlighted the underlying uncertainty and complexities. As for water footprint, he explained that the concept does not show the social impacts of changes or the benefits of gaining efficiency. He proposed to use the term 'efficiency kinetics' to explain and quantify water flows and losses passing through the myriad of pathways to final outcomes and dispositions. Chris Perry (independent consultant) explained that CROPWAT's irrigation analysis could produce an estimate of the maximum potential water consumption when using an assumption of a fully irrigated crop with no nutrient or other stresses. Where observed yields are moderate or low, this represents a substantial over estimate of the actual water footprint, and the entire error is

attributed to the so-called blue water component of the water footprint. In addition, the green water impact of most rain-fed crops is grossly overestimated because it is assumed that no water would be consumed by the alternative natural vegetation system. Often, the green water impact of agriculture is actually negative. He further mentioned that crops (and other traded commodities) contain many "virtual" inputs, and until the relative scarcity of each is known, the water footprint number alone tells us nothing of policy relevance. Pute Wu (Northwest A&F University) pointed out that previous studies generally quantified the water footprint of a crop by computing the crop evapotranspiration using the CROPWAT model at the farmland scale. This approach does not take into account irrigation water losses during the transport process from the water sources to cropland. Consequently, it could not reflect the actual water use and water use efficiency. Then, Prof. Wu introduced his work on calculating the global and China's water footprint of grain production by using a modified quantification method that takes into account irrigation losses. He introduced his work on calculating the global and China's water footprint of grain production. For China, the study found that the arid North China exported virtual water of grain production to the more water abundant South China. He also suggested that the Chinese government should set a control standard to limit the increase of the regional water footprint of grain production and has designed a mechanism to guide the virtual water importers to compensate for the water loss of virtual water exporters.

3 Quantification of water footprint

The quantification of water footprint session was chaired by Martin Tillotson (water@leeds). Keith Richards (University of Cambridge) presented the work of his interdisciplinary Cambridge group on the use of dynamic and multivariate Sankey diagrams to trace and visualize water flows through hydrological and socioeconomic systems, with the purpose of examining the land-water-energy nexus to identify the interdependence of these resources and to assess the impacts of decisions about the use of one on the availability and use of the others. Markus Pahlow (University of Twente) reviewed the four phases of Water Footprint Assessment (WFA): setting goals and scope; water footprint accounting; water footprint sustainability assessment (environmental, social, and economic); and water footprint response formulation. In his presentation, he also showed a case study of WFA for France to investigate the sustainability of production and consumption from a water resources perspective, with a focus on blue water scarcity. In the assessment, the basins of the Loire, Seine, Garonne, and Escaut have been identified as priority basins. In these basins, maize and industrial production was found to be the dominant factors in blue water scarcity. France also

externalizes its water footprint to a number of the world's more severely water-stressed river basins. Cotton, sugar cane, and rice are the three major crops that were identified as critical products. Stephan Pfister (ETH Zurich) presented on water footprint accounting in life cycle assessment (LCA). In LCA, the problems relating to WFA include ionizing radiation, toxic impacts, acidification, and eutrophication for degradative water use (grey water) and land use (difference in green water consumption). Water consumption (blue water) needs to be weighted by a spatially explicit characterization factor (e.g. water stress) in order to get a meaningful footprint that accounts for environmental relevance of water consumption. Within the LCA framework, his group assessed the environmental impacts of water footprint through weighting the water consumption with a water stress index as well as more specific characterization factors regarding human health, ecosystem quality, and resource depletion. He highlighted the problems of uncertainties in assessment of water consumption and impacts and, therefore, caution in communication of numbers is needed. Ana Serrano and Rosa Duarte (University of Zaragoza) presented a case study of calculating global water footprint and virtual water trade through a multiregion input-output model. The model incorporated 41 countries and 35 economic sectors in each country. The results showed that global water consumption increased from 1995 to 2009. They concluded that pressures on water resources have increased throughout the world, particularly in developing regions and in the case of grey water. In a structural decomposition analysis (SDA), their group found that technological improvements in high GDP and water intensity regions slowed down the growth of both green and blue water consumption. Junguo Liu (Beijing Forestry University) presented water footprint and sustainable water use based on a case study from the Heihe River Basin in an arid region in China. By integrating hydrological and economic models, Liu's group has quantified the amount of water resources and water footprint for the basin in a spatially and temporally explicit way. By comparing water footprint with water availability, he argued that water resources are used unsustainably for 8 months of the year. One important reason for such unsustainable water use came from an increasing amount of exported food products, hence virtual water exports to other regions. He concluded that virtual water trade has to be explicitly taken into account when water management policies are formulated.

4 Industrial water footprint

The industrial water footprint session was chaired by Judith Thornton (water@leeds). Justin Abbott (ARUP) presented on the experiences of ARUP in water resources management from an industry perspective. For industry, water saving includes a decrease of consumptive water use and water withdrawal, and an increase in water productivity. In his

presentation, he addressed several water saving measures that have impacts in different industrial sectors. These measures include storing flood water, capturing process water, direct dry cooling, and addressing leakage within community infrastructure. Jean-Yves Cherruault (Sustain) presented the results of a project for creating a database of the water footprint for different industrial products. There is a knowledge gap for the water footprint of materials and industrial products, which makes current estimates of the water footprint of industry uncertain. A lack of data is often cited as a primary reason for not measuring the water footprint of industrial products, so it is important to improve data and tools in this area. The project has collected 450 reports from industry and other organizations, and extracted approximately 1,500 water footprint data points from the reports. The project has also created Data Quality Indicators (DQIs) for use in this project to rate the quality of data extracted. The project has created flow charts for specific materials, breaking down production processes and populating with water data for each process. The flow charts provide a good basis to start to improve coverage and quality of data. Overall, a key challenge experienced by the project has been the poor transparency and definition in many literature sources of water footprint data especially in terms of water withdrawal and consumption.

5 From theory to practice

The from theory to practice session was chaired by Xu Zhao (Beijing Forestry University). Dabo Guan (water@leeds) presented on virtual water flows between Chinese regions. He discussed the roles of physical water transfer projects and virtual water flows in re-allocating water resources in China. He discussed whether virtual water trade can be an effective policy tool to mitigate regional water scarcity in developing countries. Guoping Zhang (Water Footprint Network, WFN) gave an overview of the development of WFA. This was followed by a presentation on how to conduct WFA at river basin level to support government policy, and for commerce at company and product levels to assist in setting up water sustainability strategies. His presentation of the case studies showed how one can translate water footprint accounts to water footprint sustainability assessment in order to incorporate WFA into policy and corporate, social, and environmental responsibilities. This is particularly relevant to the question of how useful WFA can be in feeding the policy debate and providing information and insight into designing policy measures. He also presented the main activities of the WFN, including, amongst others: (1) advancing the concept of the 'water footprint' and the WFA methodology; (2) developing WFA standards (methods, guidelines, criteria), water footprint database and WFA tools; (3) promoting exchange, communication, and dissemination of knowledge about water footprint;

and (4) supporting government bodies, international institutions, NGOs, businesses, and other organizations in implementing WFA and developing sustainable and fair water policies and strategies. Hugh Fell (Water Value) started his presentation by talking about the price of a bottle of mineral water and observed that the economic price of water in different places and situations may be significantly different. He then pointed out the importance of water in providing drinking, irrigation, and landscape amenity. Peter Easton (Easton Consult, on behalf of the European Water Partnership, EWP) introduced the initiative and the role of the European Water Stewardship (EWS) Standard. The EWP is an independent value-based nonprofit organization structured as an open and inclusive member association. The EWP helps to coordinate initiatives and activities in international water issues and promotes the EWS Standard, which it developed. The ultimate goal of the EWP is to elaborate strategies and promote actions to achieve the objectives of the Water Vision for Europe. Peter recognizes some limitations in the concepts of virtual water and water footprint, but sees their value in raising awareness of water risk and security issues. The concepts help to ‘convey the key messages in simple terms’, although not a substitute for detailed, location-specific, assessment of water issues and risk.

6 Discussion and conclusion

The plenary discussion was moderated by Junguo Liu with a focus on “Prioritization of water footprint research & applications to practical sectors”. He divided the discussion into three parts and encouraged critical comments on each part. The first part was about the current status of methods and applications related to water footprint. Since it was first introduced in 2002, the concept of water footprint has played a key role in increasing the awareness of water consumption, water resources protection and management amongst the general public, business, and policymakers. Quantification of water footprint is the first step in WFA, and there is a strong demand for methods and data. A few methods have been developed and applied for water footprint accounting, including the bottom-up approach (e.g. the supply chain method proposed by the WFN and in LCA) and the top-down approach (e.g. the input-output table method, which is also used in LCA and combined with the bottom-up approach, a “Hybrid LCA”). However, there is a need to improve model results, address uncertainty, and encourage more collaborative and comparative effort amongst the different approaches. Water footprint models should also be calibrated, compared, and validated based on field measurement data. Quantification is not the entire story, and there is more research and practical measures needed to address water footprint sustainability assessment from social, economic, and environmental perspectives, and to identify

feasible response strategies for water footprint reduction and sustainability improvement. In addition, the water footprint concept should be used to help identify solutions to practical problems, e.g. for green agricultural production and compensation mechanisms for water saving. One challenge is that to date communication and collaboration between the different communities using different water footprinting approaches have remained weak. Many researchers and practitioners are puzzled by the different types of assessments and interpretation of the WFN’s method and the draft ISO’s (draft ISO 14046) norm, particularly by the differences in the definition of “water footprint”. Multiple standards for water footprinting will doubtlessly lead to even greater confusion in the scientific and practitioner community, as well as for decision and policymakers, and the general public. There is an urgent need for more collaborative and unifying work.

The second part of the discussion was focused on the different implications of the water footprint for industrial, agricultural, and other sectors. Again, the differences among various methodological approaches were highlighted. It was argued that the LCA and ISO approaches are reliable from an industrial perspective due to their history and the product-based approach. Whilst LCA is primarily focused on products and services, the WFN approach is capable of estimating water footprint of a geographical unit at various levels ranging from river basin, a province, a country, or the entire world. However, principally the two approaches may be applied in both situations. However, the differences among these approaches to dealing with industrial products are likely to remain. It was observed that it is necessary to apply a standard approach in water footprint assessment in different sectors, which clearly would need to be agreed upon. Progress to introduce the concept of the water footprint to governments is slow, although some countries have taken a lead. For example, the Spanish government had included WFA as part of its river basin analysis in support of implementation of the Water Framework Directive (WFD). The Dutch House of Representatives has approved a resolution on the large amount of “virtual” water imported into the Netherlands. The resolution proposed that the Dutch Government, in its economic policy, will advocate that Dutch enterprises reveal their water footprint as well as reduce the impact of this footprint in countries with water scarcity issues. The new National Water Policy of India stipulates (1) a system to evolve benchmarks for water uses for different purposes, i.e. water footprints and water auditing should be developed to promote and incentivize efficient use of water; and (2) the project appraisal and environmental impact assessment for water uses, particularly for industrial projects, should, *inter alia*, include the analysis of water footprints. The “Water Code” for the Province of Buenos Aires, Argentina requires that the water footprint be included in water fee determinations. The UK Environment Agency is also considering how to reform abstraction

management. Perhaps water footprint can be used as a tool to look at the dynamics of abstraction, take care of environmental flows, and regulate wastewater discharges. Unfortunately, there were no representatives from the farming community attending the symposium. But practically, farmers understand soil moisture better than many researchers, and whether they need the water footprint concept at all is still a question. The results of water footprint assessment can contribute to the bigger picture and putting the local situation into a regional or global context. How to use the water footprint concept as a tool to solve practical problems in different sectors is still an issue. Pilot projects should be set up to apply the water footprint concept, for example, to increase water use efficiency and study the market mechanisms of water saving by farmers. If successful, such pilot projects could be expanded to include more regions and countries.

The third part of our discussion was about the future of water footprint in research and practical applications to different sectors. Developing a water footprint materials and products database was raised as one important issue, not only for industrial products but also for agriculture. However, the data have to be reliable in terms of accuracy and are often temporally and spatially explicit. There is still a lack of water use data for different industrial sectors. More reliable and accurate data of agricultural water footprints are also required. Data should be prepared by integrating on-site measured data and fieldwork as far and as often as possible. Another important issue raised is the water footprint sustainability assessment. The water footprint as just an output number attracts much criticism, and it needs to be considered in the appropriate context. There is a need for a cohesive voice and more collaborative work amongst the key research and practitioner organizations. An international research centre, forum, or alliance may help in genuinely useful dialogue and communications.

Finally, Junguo Liu asked each participant to give a brief answer to the most important research questions and issues for water footprint in the future. Some responses are as follows:

- Where does top-down analysis meet bottom-up approaches, and where is triangulation required (such as in Hybrid LCA)?
- The concept of the water footprint helps to enhance societal awareness of clean water and water pollution control.
- There is a need to agree on a robust methodology to have an impact on different water issues.
- The research and practitioner community must work together to have a sustainable water footprint concept.
- There is a need for an implementable and relevant approach.

- We should focus on understanding the meaning of water footprint for different sectors, and we should include fieldwork and demonstration work to support this.
- How do we enhance the use of water footprinting to make a change or inform governmental policy?
- We need to work together to align our views, rather than introducing opposing views.
- Our shared objective is to improve water use efficiency, and this should be the basis on which we work together in the future.
- We should not only focus on environmental issues but also use water footprint to provide us with a means to improve industrial efficiency and develop guidelines where we can improve efficiency.

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